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(54) **ULTRASOUND IMAGING PROBE**

(71) Applicant: **B-K Medical Aps**, Herlev (DK)

(72) Inventors: **Niels-Christian Sasady**, Frederiksberg (DK); **Per Ehrenreich Nygaard**, Soeborg (DK); **Bo Hansen**, Vanlose (DK)

(73) Assignee: **B-K MEDICAL APS**, Herlev (DK)

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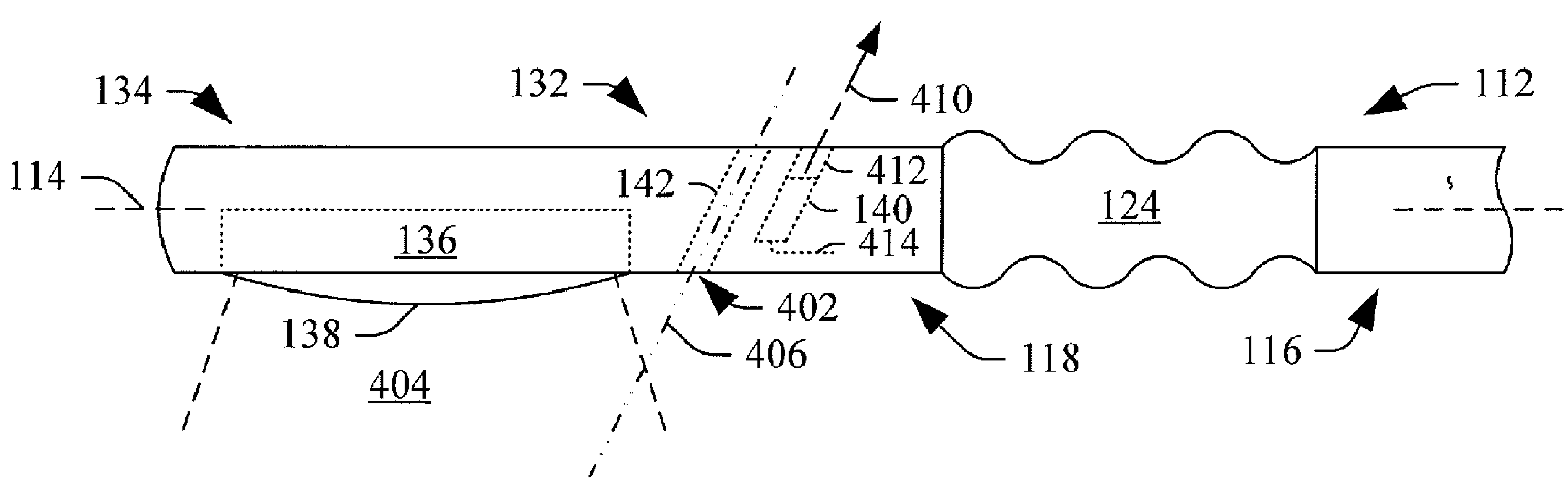
Primary Examiner — Chao Sheng
(74) *Attorney, Agent, or Firm* — Daugherty & Del Zoppo, Co. LPA

(57) **ABSTRACT**

An ultrasound probe (**104**) includes a probe head (**134**). The probe head includes a transducer array (**136**) with a transducing surface (**137**), an instrument guide (**142**), and a light source (**140**). A method includes emitting a light beam, from a light source disposed on and adjacent to a transducer array of an ultrasound imaging probe, in a direction opposite of a transducing surface of the transducer array, at an inside wall of a cavity of a subject or object. A laparoscopic ultrasound imaging probe includes a shaft, a body, an articulating member that couples the probe head, and a handle coupled to the elongate shaft. The articulating probe head includes a transducer array that generates an ultrasound signal that traverses an image plane of the transducer array, an instrument guide, and a light source arranged to emit light in a direction opposite of the image plane.

16 Claims, 8 Drawing Sheets



(51) **Int. Cl.**
A61B 1/313 (2006.01)
A61B 8/00 (2006.01)
A61B 1/00 (2006.01)
A61B 8/08 (2006.01)
A61B 8/14 (2006.01)

(52) **U.S. Cl.**
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(58) **Field of Classification Search**
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See application file for complete search history.

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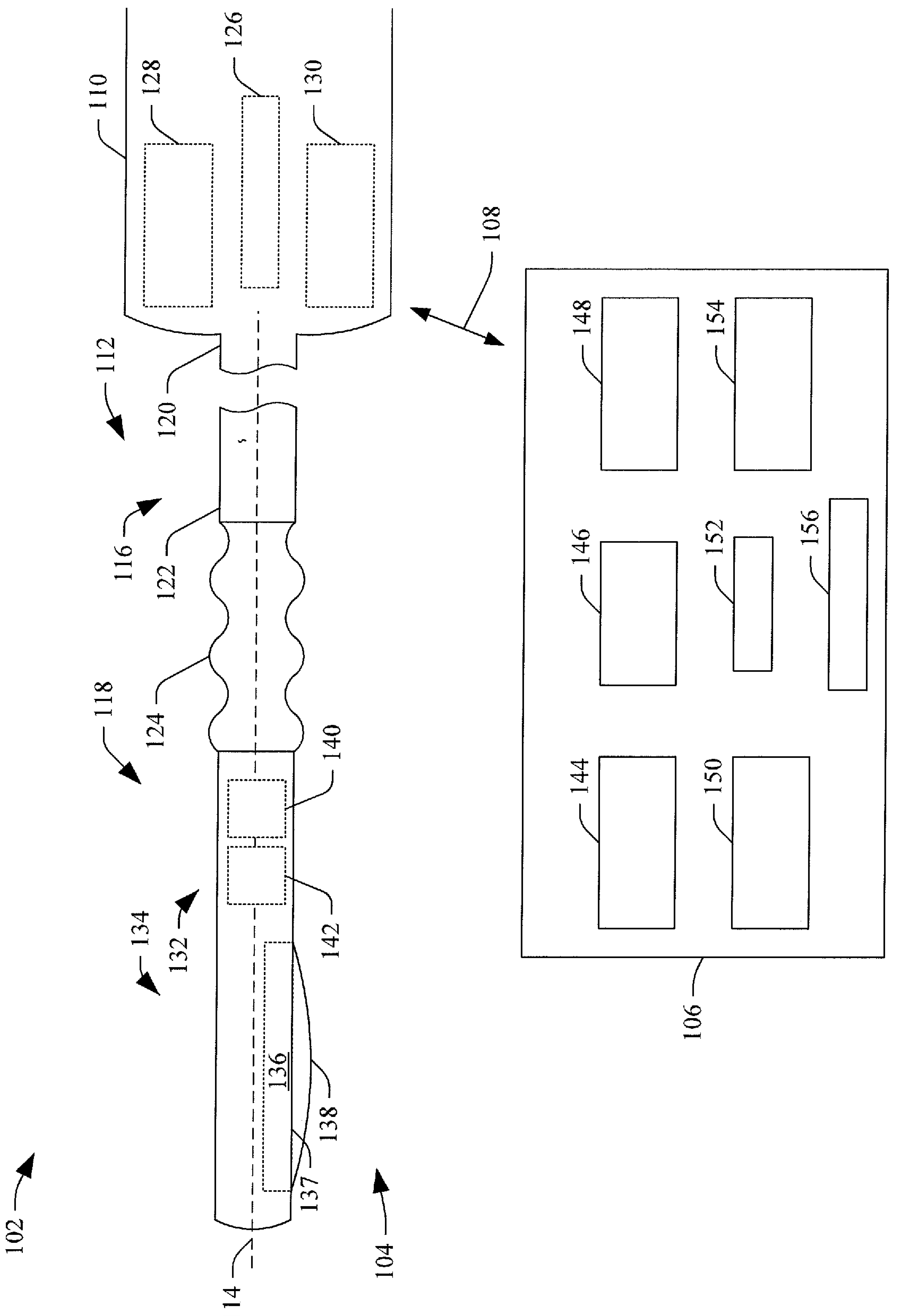
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FIGURE 1

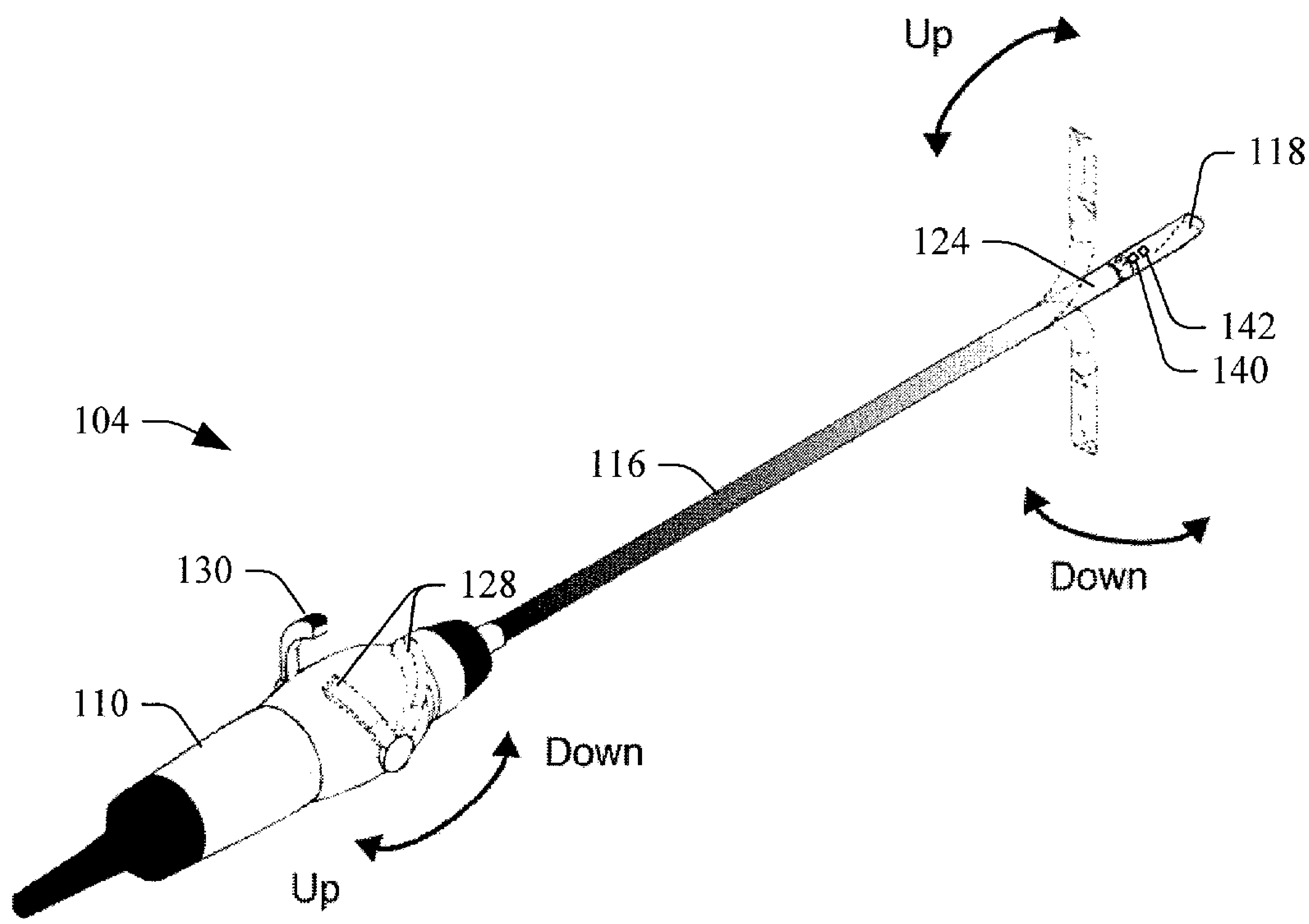


FIGURE 2

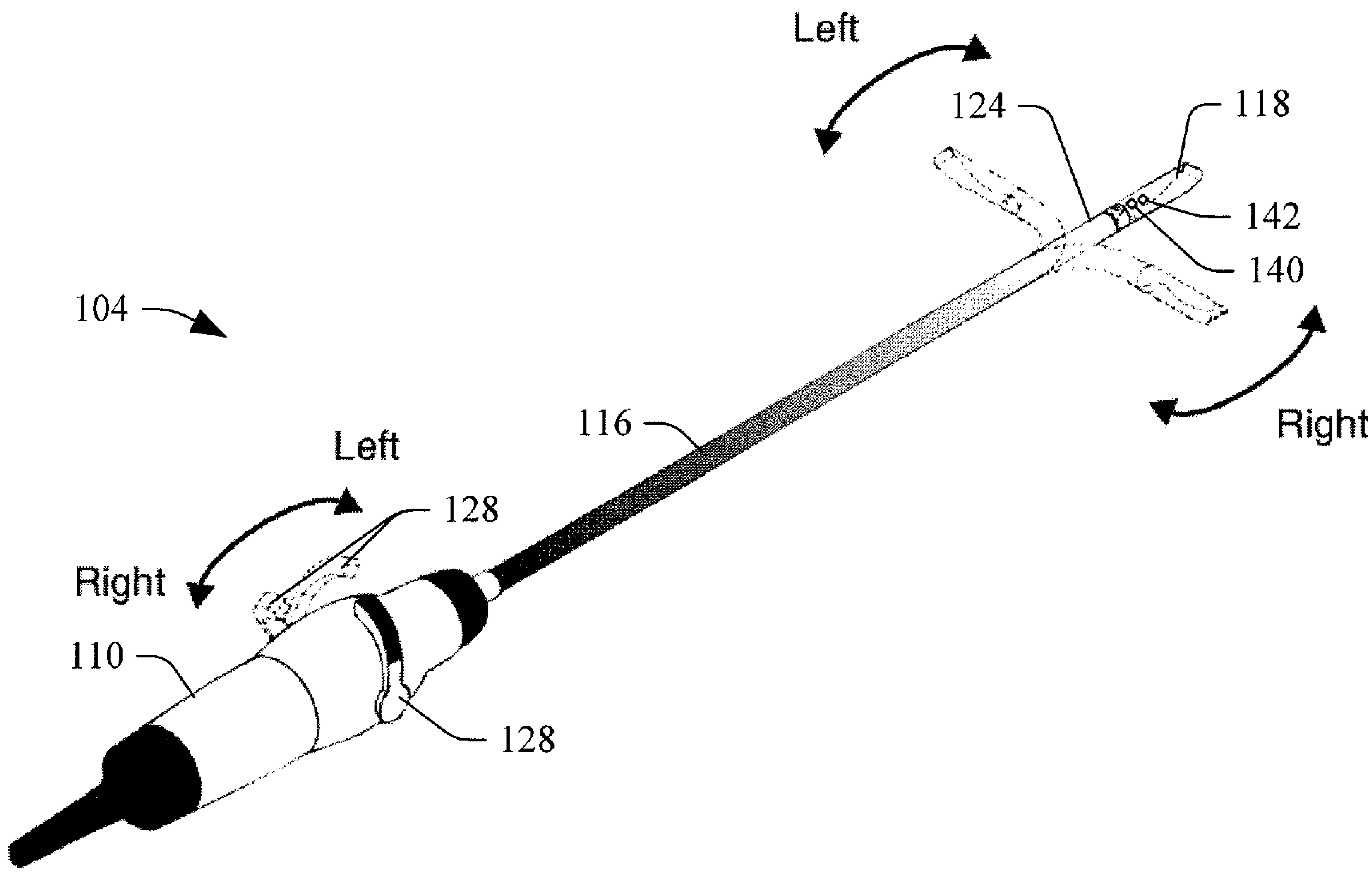


FIGURE 3

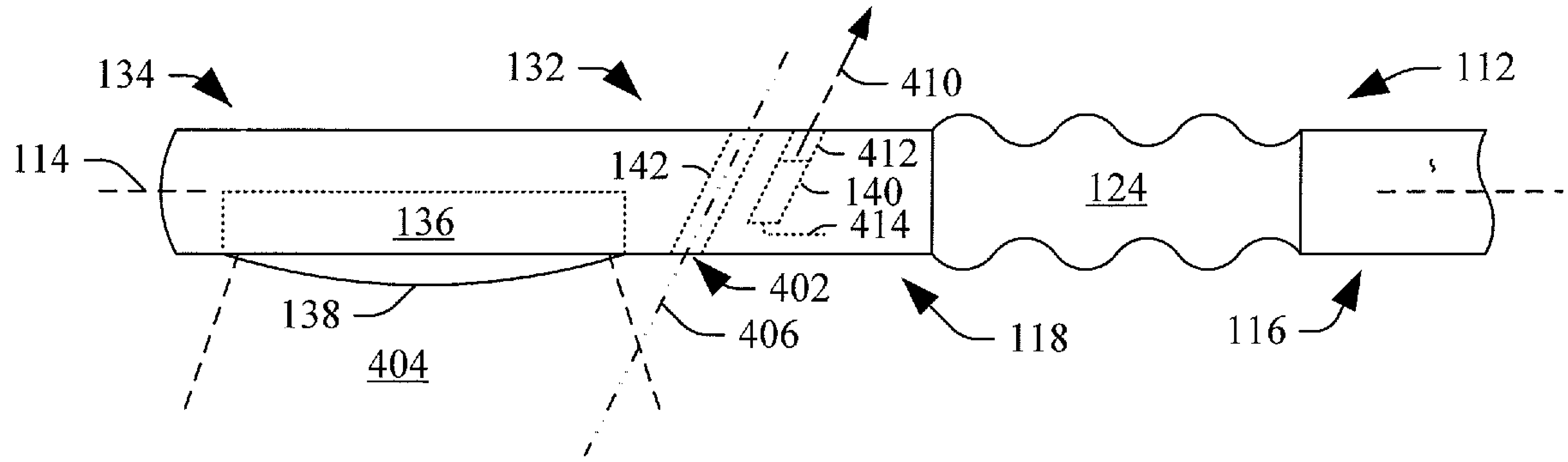


FIGURE 4

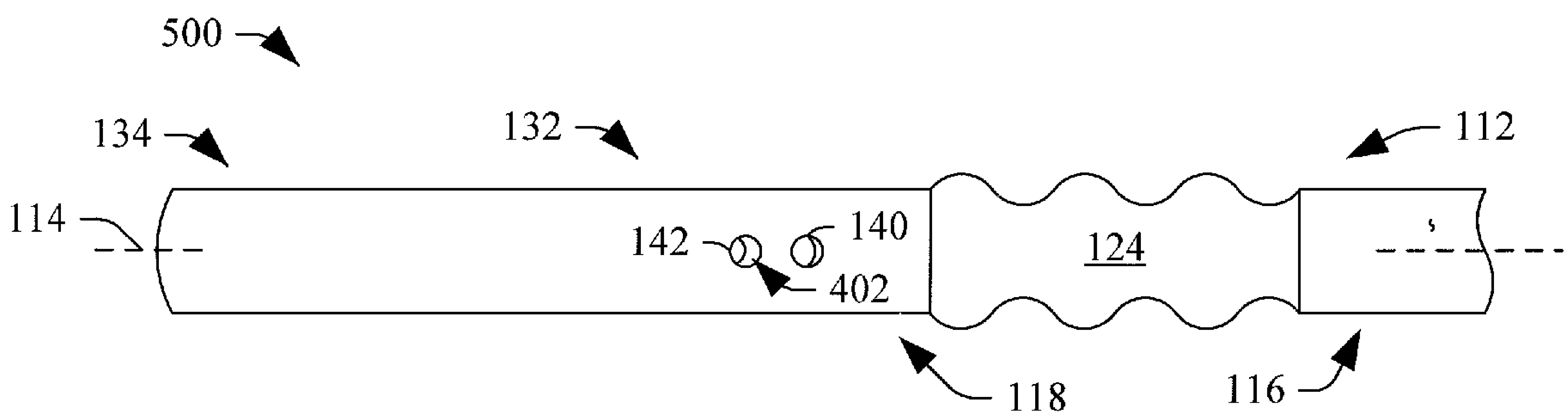


FIGURE 5

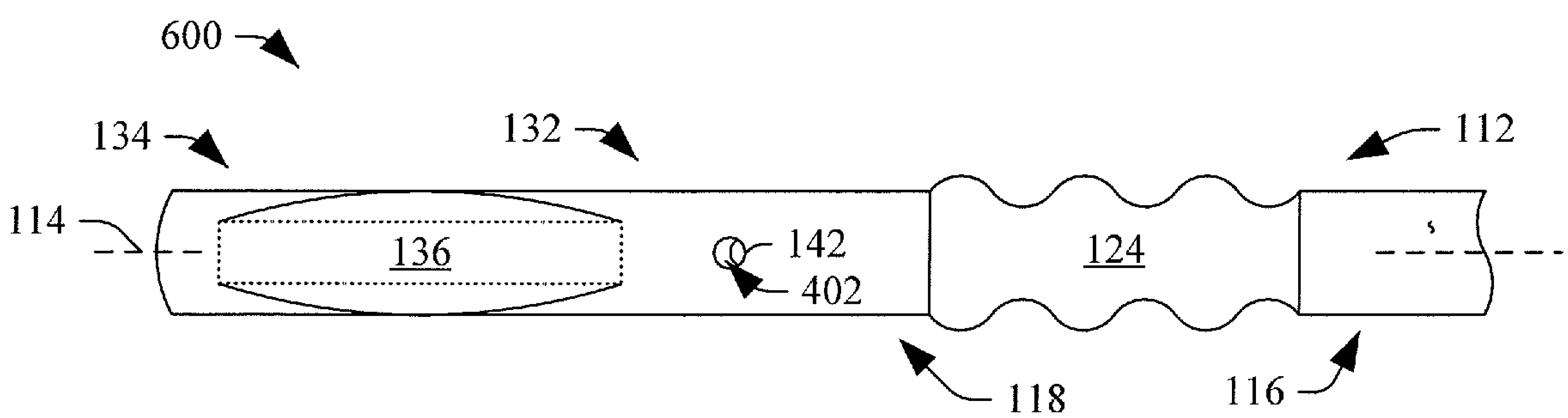
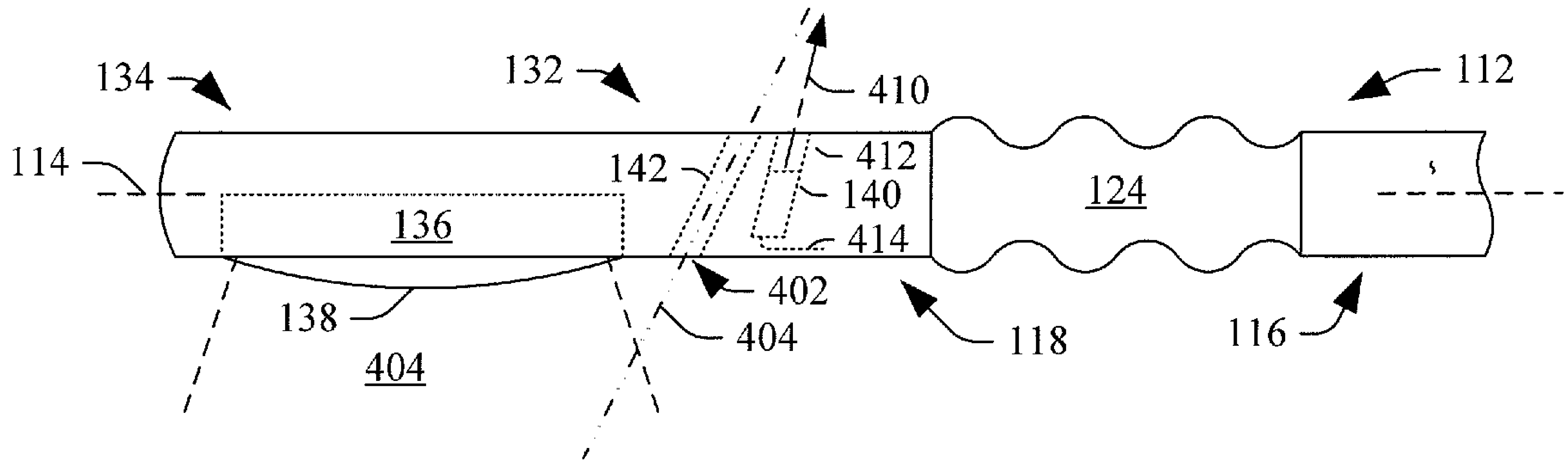


FIGURE 6



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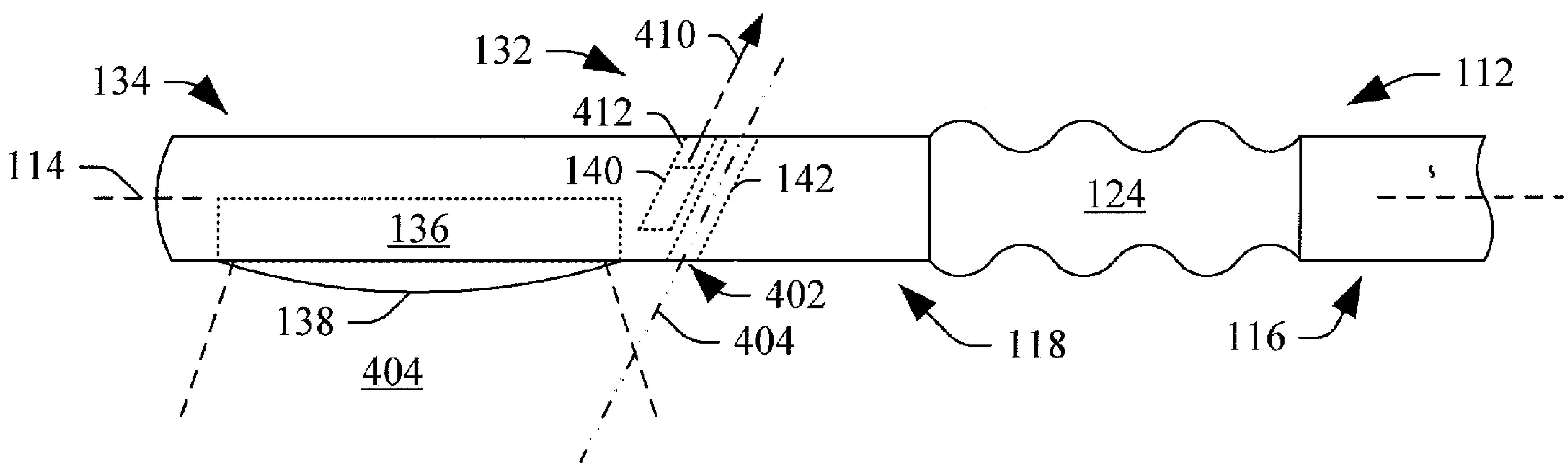

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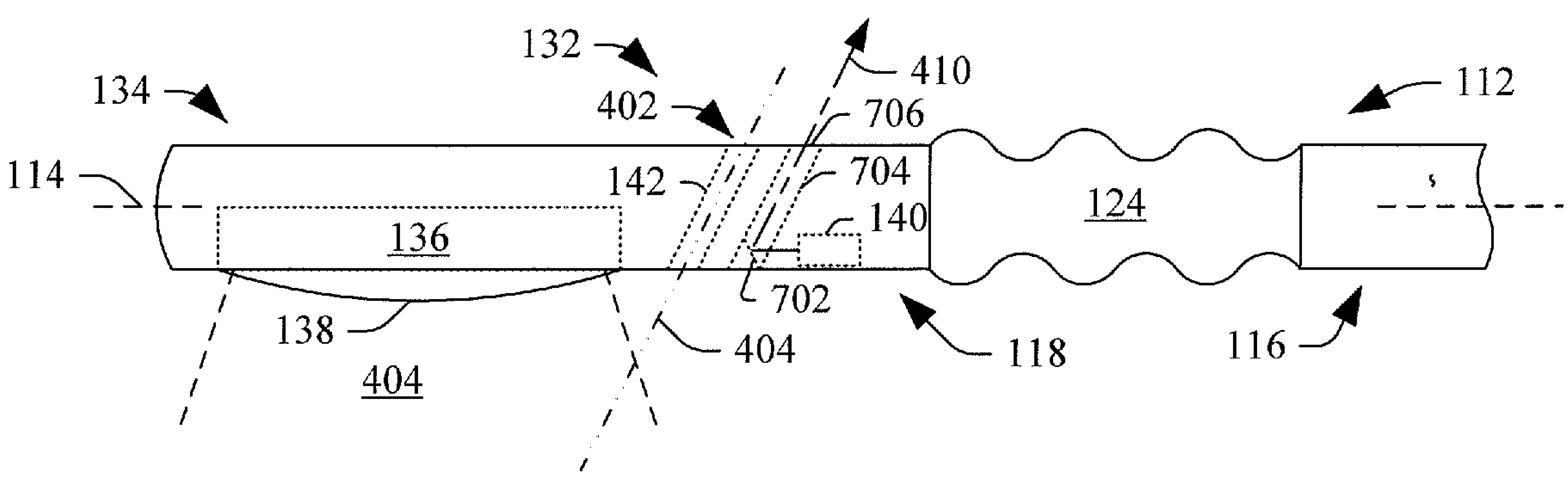
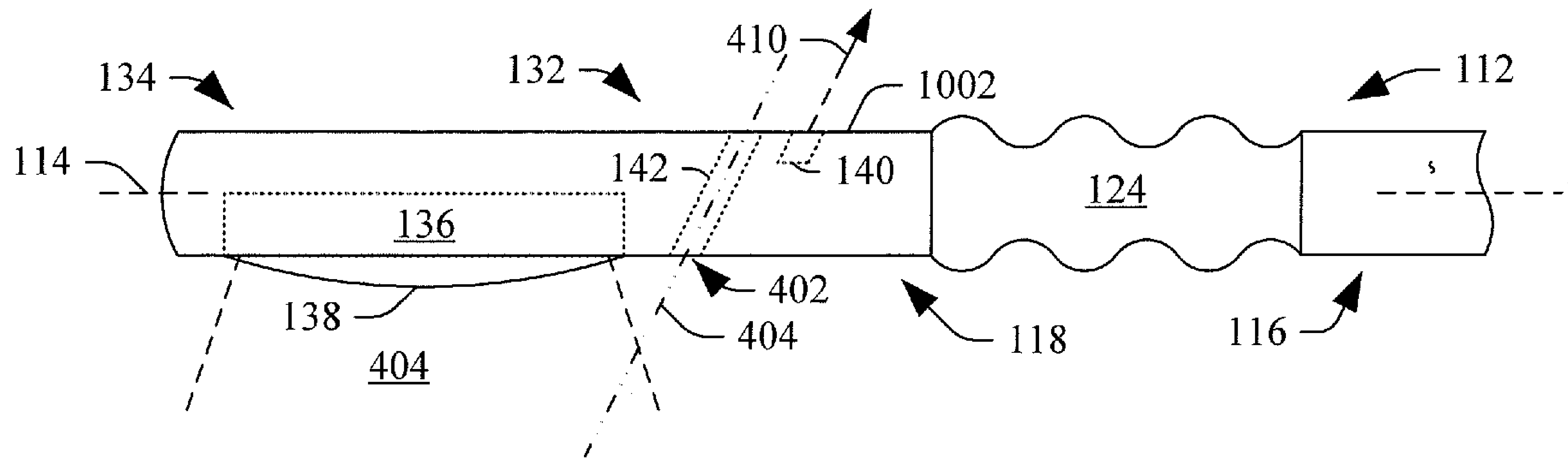


FIGURE 9



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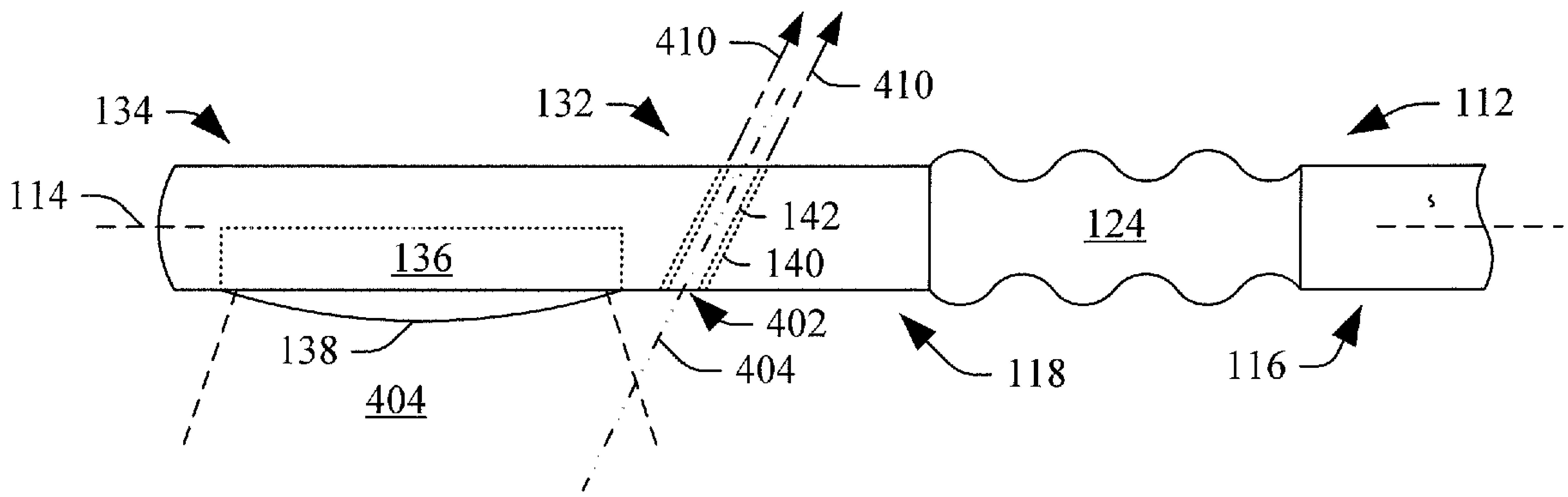

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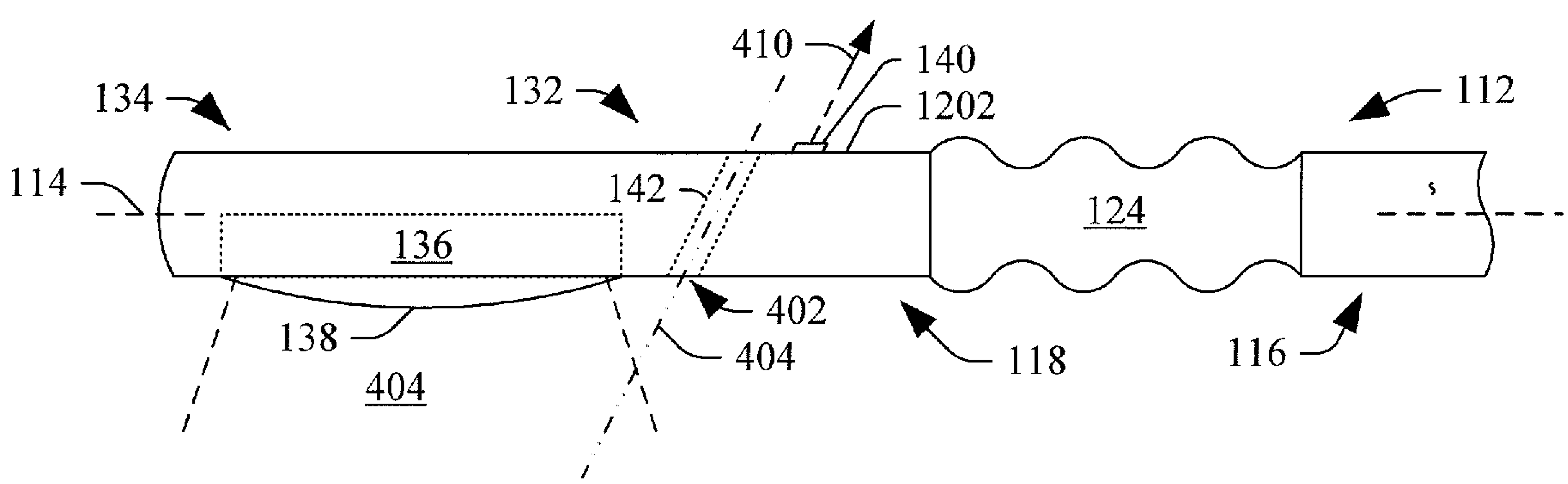

FIGURE 12

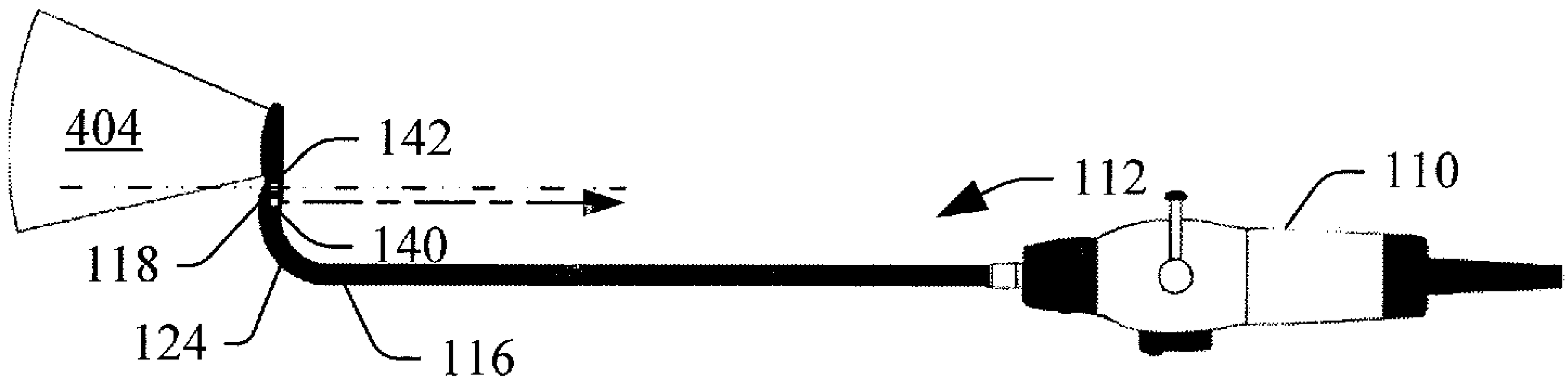

FIGURE 13

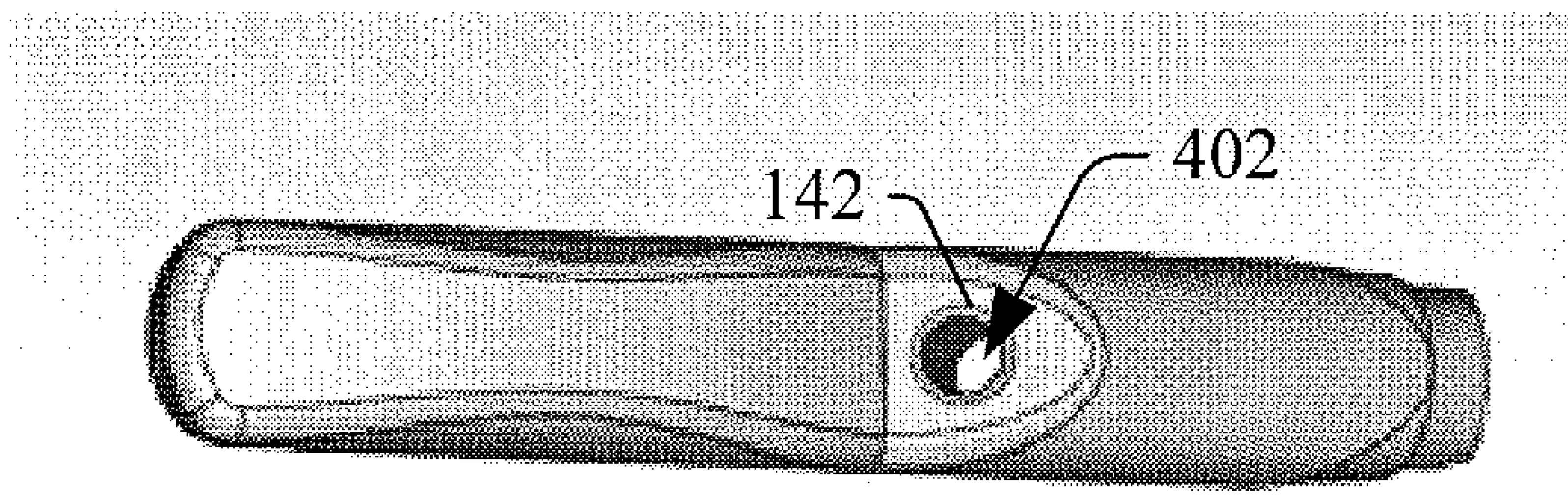

FIGURE 14

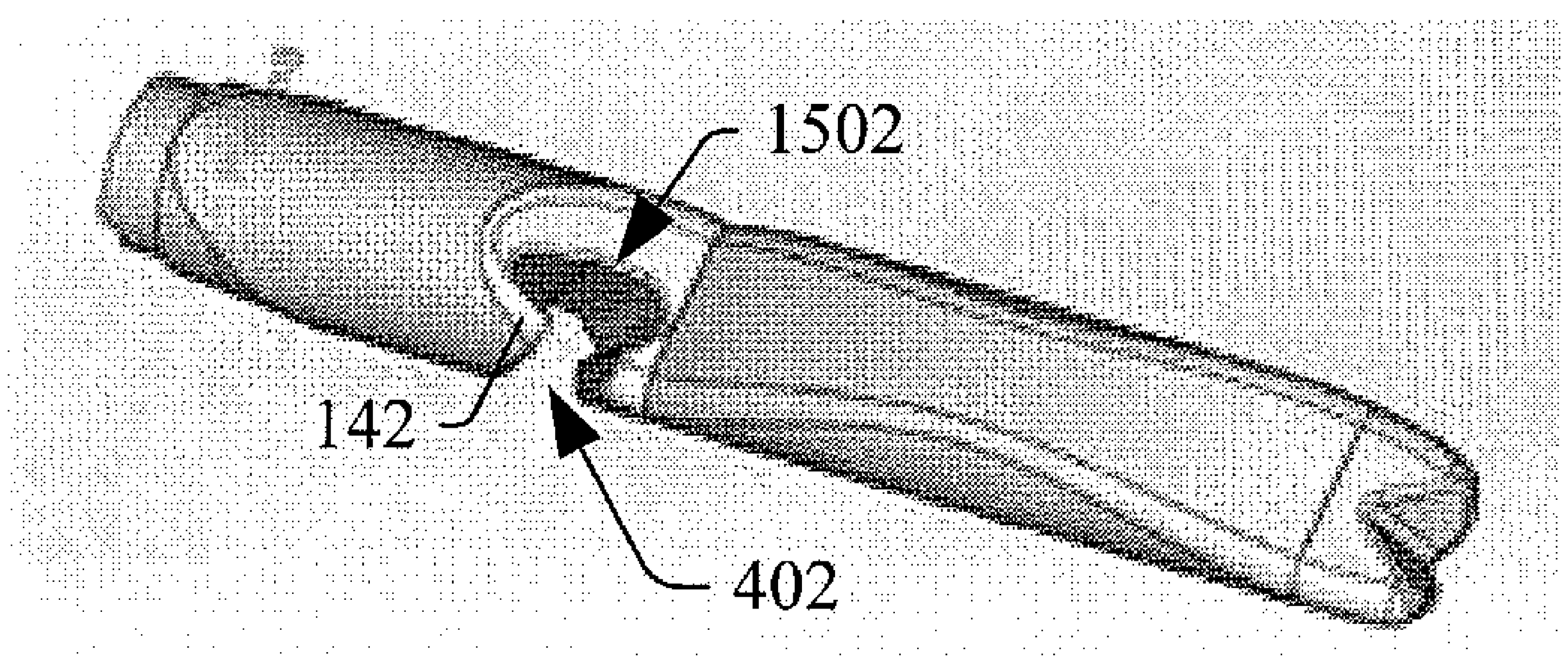

FIGURE 15

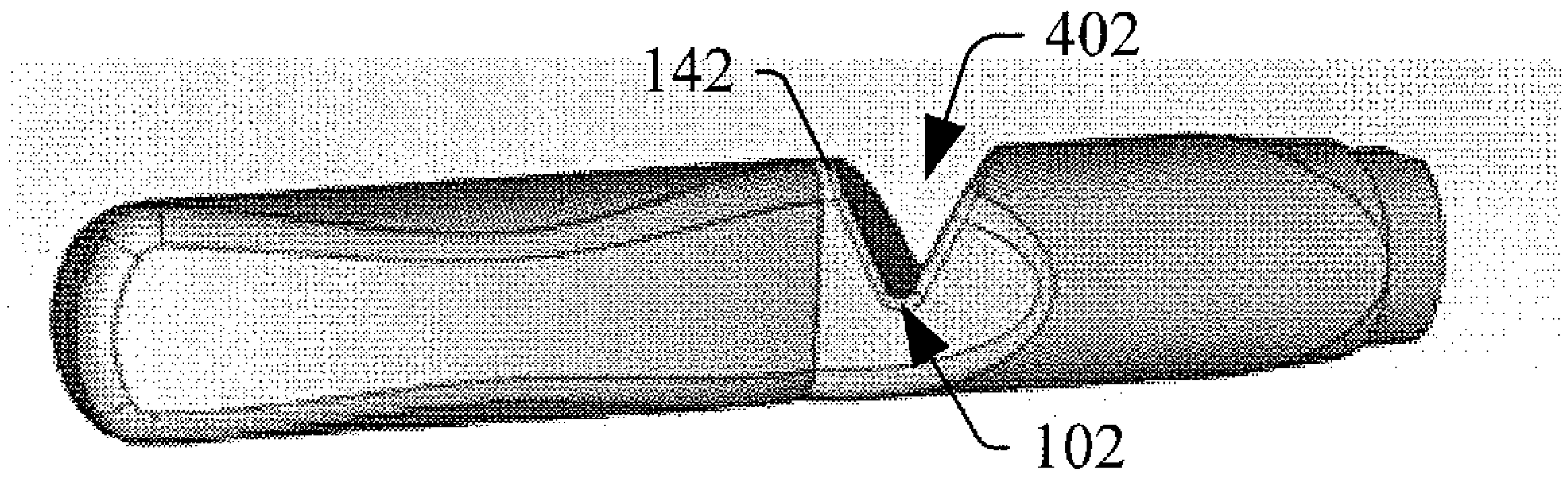

FIGURE 16

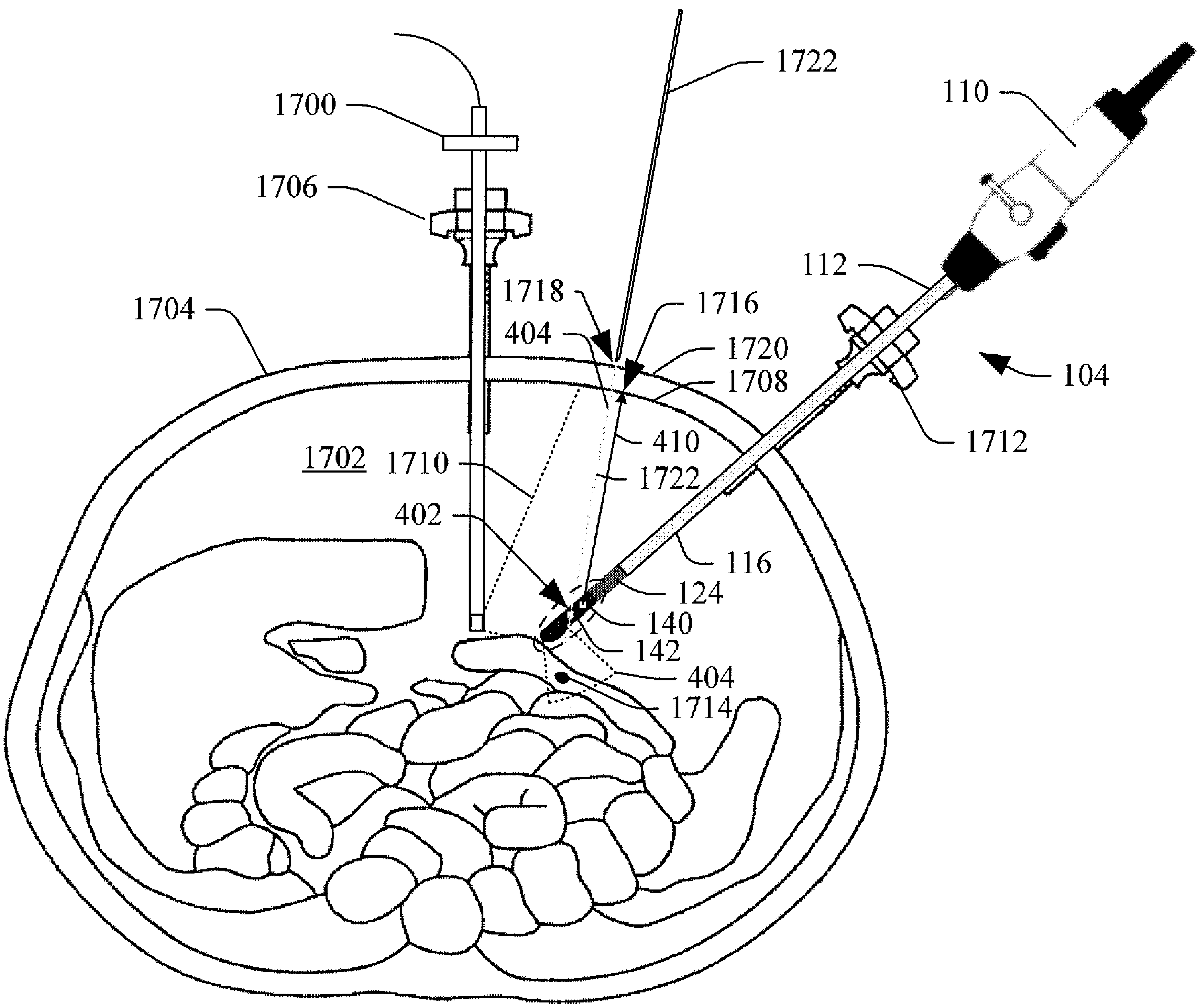
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FIGURE 17

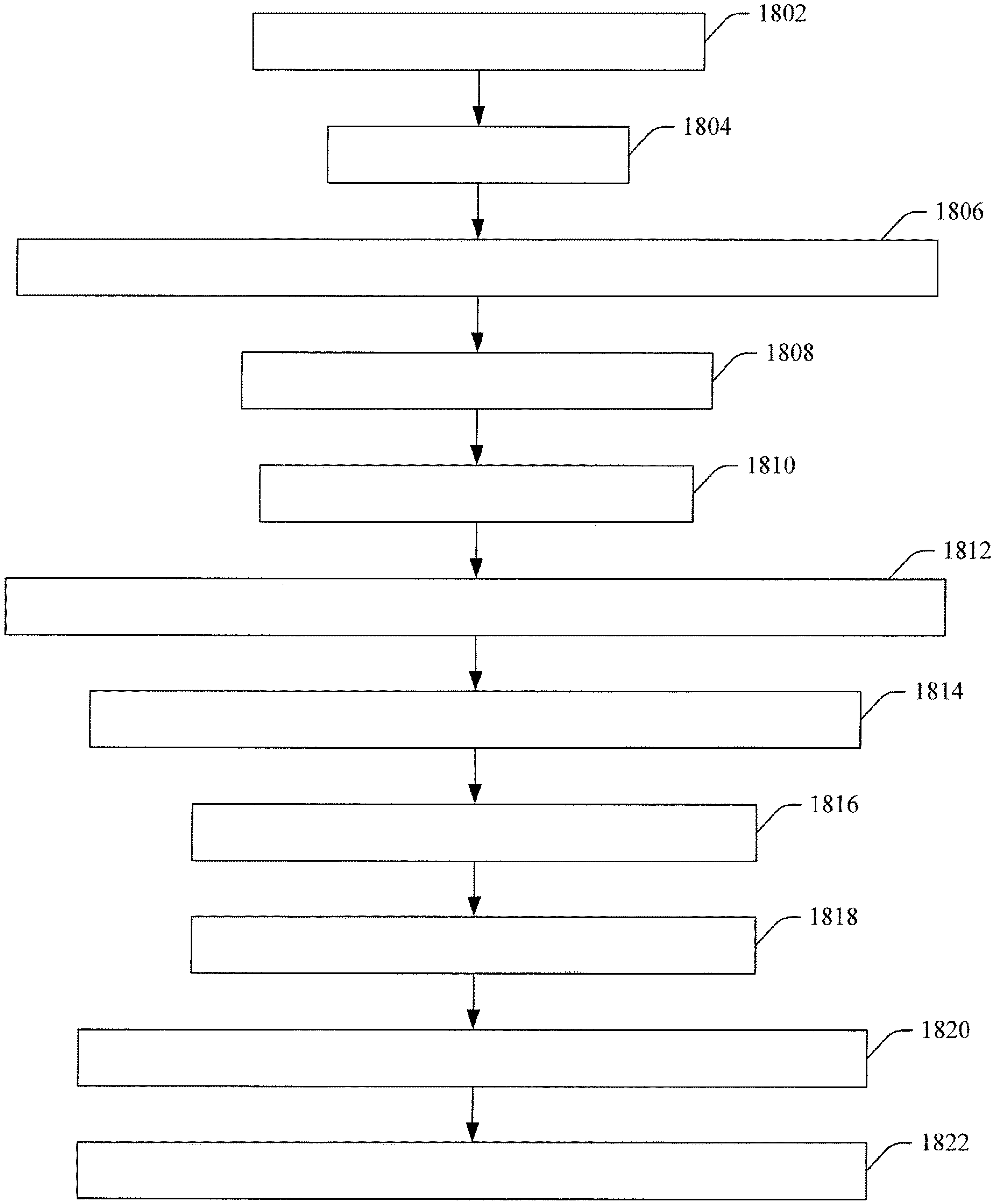

FIGURE 18

ULTRASOUND IMAGING PROBE

RELATED APPLICATION

This application is a national filing of PCT application Ser. No. PCT/IB2014/061083, filed Apr. 29, 2014, published as W02015/166302 on Nov. 5, 2015. This application claims priority to PCT application Ser. No. PCT/IB2014/061083, published as W02015/166302 on Nov. 5, 2015.

TECHNICAL FIELD

The following generally relates to ultrasound and more particularly to an ultrasound probe and is described with particular application to ultrasound imaging.

BACKGROUND

An ultrasound imaging system has included an ultrasound probe with a transducer array and a console. The ultrasound probe houses a transducer array, and the console includes a display monitor and a user interface. The transducer array transmits an ultrasound signal into a field of view and receives echoes produced in response to the signal interacting with structure therein. The echoes are processed, producing images of the scanned structure, which may be visually presented through the display monitor. An example ultrasound probe is a laparoscopic ultrasound probe. A laparoscopic ultrasound probe has been used to guide a needle to structure of interest inside of a cavity of an object or subject, e.g., in connection with a biopsy, radio frequency (RF) ablation, etc.

One approach includes using a needle that is wound around the ultrasound probe and supported adjacent to the transducer array. The transducer array and hence the needle are guided to the structure of interest through ultrasound or other images. In another approach, the needle is first attached to the transducer array outside of the cavity. Then, the other end of the needle is fed through a trocar into the cavity. Forceps are inserted into the cavity through another trocar and used to grasp the needle in the cavity and pull it up through the trocar. Concurrently, the ultrasound probe is fed into the cavity through the first trocar. The transducer array and hence the needle can then be guided to the structure.

Examples of the above two approaches are described in U.S. Pat. No. 6,086,169, filed Apr. 19, 1996, and entitled "Method and an apparatus for the insertion of a needle guide into a patient in order to remove tissue samples," which is incorporated by reference in its entirety herein. Unfortunately, the above approaches utilize a long flexible needle that can be expensive (e.g., relative to a free hand needle) and difficult to use. Furthermore, the second approach requires predicting where to insert the needle through the cavity wall to reach the structure of interest, which may require a high degree of skill, and may result in a less than optimal site for the guiding the needle to the structure of interest.

SUMMARY

Aspects of the application address the above matters, and others.

In one aspect, an ultrasound probe includes a probe head. The probe head includes a transducer array with a transducing surface, an instrument guide, and a light source.

In another aspect, a method includes emitting a light beam, from a light source disposed on and adjacent to a transducer array of an ultrasound imaging probe, in a direction opposite of a transducing surface of the transducer array, at an inside wall of a cavity of a subject or object.

In another aspect, a laparoscopic ultrasound imaging probe includes a shaft, a body, an articulating member that couples the probe head, and a handle coupled to the elongate shaft. The articulating probe head includes a transducer array that generates an ultrasound signal that traverses an image plane of the transducer array, an instrument guide, and a light source arranged to emit light in a direction opposite of the image plane.

Those skilled in the art will recognize still other aspects of the present application upon reading and understanding the attached description.

BRIEF DESCRIPTION OF THE DRAWINGS

The application is illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

FIG. **1** schematically illustrates an example probe with a light source and an instrument guide;

FIG. **2** illustrates example up/down movement of a head of the probe;

FIG. **3** illustrates example right/left movement of the head of the probe;

FIG. **4** schematically illustrates a side view of the head of the probe;

FIG. **5** schematically illustrates a top down view of the head of the probe;

FIG. **6** schematically illustrates a bottom up view of the head of the probe;

FIG. **7** schematically illustrates a variation of the light source and the instrument guide;

FIG. **8** schematically illustrates another variation of the light source and the instrument guide;

FIG. **9** schematically illustrates another variation of the light source and the instrument guide;

FIG. **10** schematically illustrates another variation of the light source and the instrument guide;

FIG. **11** schematically illustrates another variation of the light source and the instrument guide;

FIG. **12** schematically illustrates another variation of the light source and the instrument guide;

FIG. **13** schematically illustrates another variation of the light source and the instrument guide;

FIG. **14** schematically illustrates a variation of the instrument guide;

FIG. **15** schematically illustrates another variation of the instrument guide;

FIG. **16** schematically illustrates another variation of the instrument guide;

FIG. **17** illustrate the probe in operation; and

FIG. **18** illustrates an example method.

DETAILED DESCRIPTION

FIG. **1** schematically illustrates an imaging system **102** such as ultrasound imaging system. The imaging system **102** includes an ultrasound probe **104** and a console **106**. The ultrasound probe **104** and the console **106** are in electrical communication through a communications channel **108**, which may be through a wireless or a hard wire (e.g., electro-mechanical connector, a cable, etc.) communications channel.

The ultrasound probe **104** includes a handle **110** and an elongate shaft **112** having a long axis **114**. The elongate shaft **112** includes a body **116** and a head **118**, both aligned along the long axis **114**. The body **116** includes a first end **120** and a second opposing end **122**. The first end **120** of the body is affixed to the handle **110**. An articulating member **124** couples the second end **122** of the body and the head **118**. The articulating member **124** articulates in at least four directions. In a variation, the articulating member **124** is omitted and the ultrasound probe **104** is a rigid, or non-articulating, probe.

The handle **110** includes electronics **126**, a first actuator **128** and a second actuator **130**. The electronics **126** provide power and/or data channels. The first actuator **128** actuates the articulating member **124** to control up/down movement of the head **118**. The second actuator **130** actuates the articulating member **124** to control left/right movement of the head **118**. FIGS. **2** and **3** respectively show example actuation of the actuators **128** and **130** and corresponding up/down and left/right movement of the head **118**.

An example of a transducer probe with an articulating head is the transducer data type 8666, which is a product of BK-Medical ApS, a company of Herlev, Denmark, which is a wholly owned subsidiary of Analogic Corporation, a company of MA, USA. Example approaches for articulating an articulating head of a transducer probe with an articulating head are described in patent applications PCT/IB2011/001622 and PCT/IB2013/000043, which are incorporated herein by reference in their entireties.

The head **118** includes a first end region **132** and a second opposing end region **134**. A transducer array **136** is disposed in the second end region **134**. The transducer array **136** includes a one-dimensional (1D) or two-dimensional (2D) array of transducer elements. Suitable arrays include linear, curved (e.g., convex), phased, etc. The transducer array **136** can be fully populated or spares. The transducer array **136** includes a transducing surface **137**. An ultrasonic window **138** is disposed adjacent to a transducing side of transducer array **136**.

A light source **140** and an instrument guide **142** are disposed in the first end region **132**. As described in greater detail below, the light source **140** is arranged with respect to the instrument guide **142** to illuminate, when inside a cavity, a region on an inside wall of cavity, which aligns with a path traversing the slot of the instrument guide **142**. As such, a clinician, e.g., guided by a laparoscopic camera, can identify an instrument insertion point on an outside wall of the cavity. For example, the clinician can press around on the outside of the cavity until the depression on the inside wall of the cavity aligns with the illuminated region. This assures the clinician that the insertion point will allow a free hand instrument to reach the instrument guide **142**, e.g., under ultrasound image guidance, for guidance of the instrument to a structure of interest inside of the cavity.

The probe **104** can be used for laparoscopic, endoscopic, and/or other ultrasound applications, and can be used to assist personnel, for example, with an interventional procedure such as a liver, gall bladder, tumor biopsy, etc., guide personnel, for example, with biopsy, RF ablation, chemical injection, etc. As shown, the probe **104** is employed with the console **106**. In other embodiments, the probe **104** can be employed with other consoles and/or devices, via cable or wireless communication.

The console **106** includes a transmit circuit **144** and a receive circuit **146**. The transmit circuit **144** controls the phasing and/or time of actuation of the individual elements of the transducer array **136**, which allows for steering and/or focusing the transmitted beam. The receive circuit **146** receives signals indicative of the echoes received by the transducer array **136** and can beamform (e.g., delay and sum) the received echoes.

The console **106** further includes an echo processor **148** that processes received echoes. Such processing may include beamforming (e.g., delay and sum) the echoes. For example, with B-mode, the echo processor **148** can produce a sequence of focused, coherent echo samples along focused scanlines of a scanplane. Other processing may lower speckle, improve specular reflector delineation, and/or includes FIR filtering, IIR filtering, etc.

The console **106** further includes a scan converter **150** that scan converts (using analog and/or digital scan converting techniques) the frames of data to generate data for display, for example, by converting the data to the coordinate system of the display. This may include changing the vertical and/or horizontal scan frequency of signal based on the display. The console **106** further includes a display **152** that visually presents the scan converted data.

The console **106** further includes a user interface (UI) **154** with one or more input devices (e.g., a button, a knob, a touchscreen, etc.) and/or one or more output devices (e.g., a display monitor, an audio presenter, etc.), which allows for interaction with the system **102**. The console **106** further includes a controller **156** that controls at least one of the transmit circuit **144**, the receive circuit **146**, the echo processor **148**, the scan converter **150**, the display **152** or the user interface **154**.

At least one of the components of the console **106** can be implemented by way of computer readable instructions, encoded or embedded on computer readable storage medium (which excludes transitory medium) including physical memory and/or other non-transitory medium, which, when executed by a computer processor(s), causes the processor (s) to carry out functions. At least one of the instructions, optionally, is carried by a signal, carrier wave or other transitory medium.

FIGS. **4**, **5** and **6** illustrate a non-limiting example of the light source **140** and the instrument guide **142**. FIG. **4** shows a side view, FIG. **5** shows a top down view into a top **500**, and FIG. **6** shows a bottom up view from a bottom **600**.

The instrument guide **142** includes a material free region or slot **402**. The slot **402** is configured to allow an instrument to pass through the instrument guide **142**. For example, where the instrument is a needle, the slot **402** may have a diameter that allows a needle having a gauge in a range from 14 to 20 G (or other over or non-overlapping range) to pass. For this, the diameter may be on the order of the largest needle gauge (1.600 mm for 14 G) plus a margin (e.g., 0.050 mm or higher).

The slot **402** is angled (with respect to the long axis of the shaft **112**) and extends in a direction from the transducer array **136** towards the articulating region **124**. This allows a portion of an instrument advancing from the side of the handle **100** to enter the slot **402**, traverse there through, and enter a field of view **404** of the transducer array **136**. As an example, FIG. **4** shows an imaginary path **406** extending through the slot **402** and into the field of view **404**. The angle of the illustrated slot **402** is not limiting.

The light source **140**, similar to the slot **402**, is angled with respect to the long axis of the shaft **112**. In the illustrated embodiment, the angle of each of the light source

140 and the slot 402, with respect to the long axis of the shaft 112, is the same. The light source 140 is also off-set, along the long axis, from the slot 402. As such, the light emitted therefrom traverses a path 410, which is parallel to the path 406, in a direction from the transducer array 136 in a direction of the articulating region 124.

A window 412 provides a path for the light source 140 to exit the shaft 112. The window 412 can include a lens, a prism, a filter, and/or other optical element. With the above described configuration, a central location of the light emitted from the light source 140 will illuminate a region on the inside wall of the cavity that is off-set from the insertion point of the instrument in the cavity wall. As discussed herein, this allows the clinician to locate the insertion point for the instrument from inside the cavity.

The light source 140 can include one or more light emitting elements such as one or more of a laser, a light emitting diode (LED), an optic fiber, or the like. The light source 14 emits a light beam that generates a light spot (e.g., on an incident surface) having a diameter in a range of one (1) millimeter to fifty (50) millimeters. For example, in one instance, the light source 140 emits a light beam that generates a light spot with a diameter in a range of two (2) millimeters to four (4) millimeters.

Power for the light source 140 can be from an internal battery (re-chargeable or disposable), capacitor, etc. located in the shaft 112, the handle 110 and/or otherwise in connection with the ultrasound probe 104, and/or from an external power supply, for example, from the console 106 and/or otherwise. FIG. 4 shows an example in which power is supplied to the light source 140 through an internal electrical path 414.

Variations are described next.

FIG. 7 illustrates a variation in which the light source 140 and the instrument guide 142 are at different angles. With this embodiment, the central location of the light emitted from the light source 140 will illuminate a region on the inside wall of the cavity that is closer to the insertion point and, in some instances, depending on a distance from the light source 140 and the instrument guide 142, may align with the insertion point.

FIG. 8 illustrates a variation in which the location of the light source 140 and the instrument guide 142 along the long axis 114, with respect to transducer array 136, is reversed, and the light source 140 is on the transducer array 136 side and the instrument guide 142 is on the articulating member 124 side. In FIGS. 4-6, the light source 140 is on the articulating member 124 side and the instrument guide 142 is on the transducer array 136 side.

FIG. 9 illustrates a variation in which the light source 140 emits light in a direction of the long axis 114 and an element 702 reflects the light down a light pipe 704 and out of a window 706. The element 702 may include a mirror and/or reflective surface and/or coating. FIG. 10 illustrates a variation in which the light source 140 is flush 1002 with a surface of the shaft 112.

FIG. 11 illustrates a variation in which the light source 140 surrounds an outer perimeter of the instrument guide 142. In this variation, a central region of the light pattern on the inside wall of the cavity identifies the insertion point. FIG. 12 illustrates a variation in which the light source 140 protrudes from a surface 1202 of the shaft 112. In this variation, the window 412 is omitted.

FIG. 11 illustrates a variation in which the light source 140 surrounds an outer perimeter of the instrument guide 142. In this variation, a central region of the light pattern on the inside wall of the cavity identifies the insertion point.

FIG. 12 illustrates a variation in which the light source 140 protrudes from a surface 1202 of the shaft 112. In this variation, the window 412 is omitted.

FIG. 13 illustrates a variation in which the light source 140 and the instrument guide 142 are not angled with respect to the head 118. In FIG. 13, the head 118 is shown in an articulated position.

FIGS. 14, 15 and 16 illustrate non-limiting examples of the instrument guide 142. In FIG. 14, the slot 402 of the instrument guide 142 is cylindrical in shape. In FIG. 15, the slot 402 of the instrument guide 142 includes a "C" shape cut out 1502. In FIG. 16, the slot 402 of the instrument guide 142 includes a "V" shaped cut out 1602. Other variations are also contemplated herein. In general, the slot 402 is configured to allow an instrument of interest to pass there through.

FIG. 17 shows the probe 104 in use. In FIG. 17, a laparoscopic camera 1700 is inserted into an abdominal cavity 1702 of a patient 1704. The abdominal cavity 1702 is held in a distended state through a gas supplied by an insufflator or the like. The laparoscopic camera 1700 is inserted into the abdomen cavity 1702 through a first trocar 1706. The laparoscopic camera 1700 is operated so that an inside wall 1708 of the abdominal cavity 1702 is in its field of view 1710.

The head 118 of shaft 112 is also inserted into the abdominal cavity 1702 of the patient 1704. The head 118 is inserted into the abdomen cavity 1702 through a second trocar 1712. The head 118 is positioned so that a structure of interest 1714 is in the field of view 404. In this position, the light source 140 emits the light 410 which illuminates a region 1716 on the inside wall 1708 of the abdominal cavity 1702. The laparoscopic camera 1700 generates an image or video which shows the illuminated region 1716.

From the illuminated region 1716, an insertion point 1718 is located on an outside wall 1720 of the abdominal cavity 1702 by pressing on the outside wall 1720 and identifying the point at which the depression inside the wall coincides with the illuminated region 1716. A needle instrument 1722 is inserted at the insertion point 1718 and is advanced along the path 404 to the slot 402 in the instrument guide 142. The needle instrument 1722 is guided along the path 404 to the slot 402 using ultrasound and/or other image data and advanced to the structure of interest 1714 using the instrument guide 142 and the ultrasound and/or other image data.

FIG. 18 illustrates a method for employing the probe 104.

It is to be appreciated that the order of the following acts is provided for explanatory purposes and is not limiting. As such, one or more of the following acts may occur in a different order. Furthermore, one or more of the following acts may be omitted and/or one or more additional acts may be added.

At 1802, the head 118 of the probe 204 is inserted into a cavity of a subject or object.

At 1804, the transducer array 126 of the probe 204 is excited to acquire image data of structure in the cavity.

At 1806, the image data is visually observed to locate a structure of interest in the cavity.

At 1808, the light source 140 of the probe 104 is activated, illuminating a region on the inside wall of the cavity.

At 1810, an operator presses on an outside surface of the cavity.

At 1812, a camera in the cavity acquires data showing the illuminated region and depressions from the pressing.

At 1814, an instrument insertion point is identified in response to a depression coinciding with the illuminated region.

At 1816, an instrument is inserted at the insertion point.

At **1818**, the instrument is guided to the slot **402** of the instrument guide **142**, under image data and/or other guidance.

At **1820**, the instrument is advanced in the instrument guide **142** to the structure of interest, under guidance of the instrument guide and image data and/or other guidance.

At **1822**, a procedure is performed on the structure of interest with the instrument.

The application has been described with reference to various embodiments. Modifications and alterations will occur to others upon reading the application. It is intended that the invention be construed as including all such modifications and alterations, including insofar as they come within the scope of the appended claims and the equivalents thereof.

What is claimed is:

1. An ultrasound probe, comprising:

an elongate shaft having a long axis, a first end, a second opposing end that spatially opposes the first end, a first side and a second opposing side that spatially opposes the first side;

a probe head disposed at the first end and including:

an ultrasonic window disposed on a sub-portion of only the first side; and

a transducer array disposed behind the ultrasonic window and along the long axis, wherein the transducer array includes a transducing surface that is parallel to the long axis and transverse to the first and second ends and is configured to emit from the first side through the ultrasound window and in a first direction away from the probe head;

a slot that extends entirely through the elongate shaft from the first side to the second opposing side, that is angled relative to the transducer array and the long axis of the elongate shaft, and that is configured as an instrument guide;

a recess in a surface of the second side of the elongate shaft, spatially offset from the transducer array along the long axis, and angled relative to the transducer array and the long axis of the elongate shaft; and

a light source disposed in the recess, angled relative to the transducer array and the long axis of the elongate shaft, and configured to emit light from the second side in a second direction away from the probe head, away from the first end, towards the second end, and opposite the first direction.

2. The ultrasound probe of claim **1**, further comprising a second different window disposed in the recess between the light source and the second side of the elongate shaft.

3. The ultrasound probe of claim **1**, wherein the transducer array, the light source, or both the transducer array and the light source are stationarily mounted in the probe.

4. The ultrasound probe of claim **1**, wherein the slot has a diameter in a range of 0.413 millimeters to 3.00 millimeters.

5. The ultrasound probe of claim **1**, wherein an instrument path of the slot and a light emission path of the recess are parallel to each other.

6. The ultrasound probe of claim **1**, wherein the light source includes a laser, a light emitting diode, or an optical fiber.

7. The ultrasound probe of claim **1**, wherein the slot is cylindrical in shape.

8. The ultrasound probe of claim **1**, wherein an instrument path of the slot and a light emission path of the recess are not parallel to each other.

9. The method of claim **1**, wherein the slot is located between the transducer array and the recess.

10. The ultrasound probe of claim **1**, wherein the recess is located between the transducer array and the slot.

11. The ultrasound probe of claim **1**, wherein an end of the light source is flush with the surface of the second side of the elongate shaft.

12. The ultrasound probe of claim **1**, wherein the slot is inside of the recess and the light source includes only a single light emitting element that surrounds the outer perimeter of the slot.

13. The ultrasound probe of claim **1**, wherein the light source is arranged with respect to the instrument guide to illuminate a region that aligns with a path traversing the slot.

14. The ultrasound probe of claim **1**, wherein the light source is configured to produce light having a diameter in a range of one (1) millimeter to fifty (50) millimeters.

15. The ultrasound probe of claim **1**, further comprising:

a body with two ends; and

a handle, wherein one of the two ends of the body is coupled to the probe head and the other of the two ends of the body is coupled to the handle.

16. The ultrasound probe of claim **15**, the elongate shaft, further comprising:

an articulating member that couples the probe head and the first end.

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